# Le sorgho: une opportunité pour produire de l'éthanol et des graines

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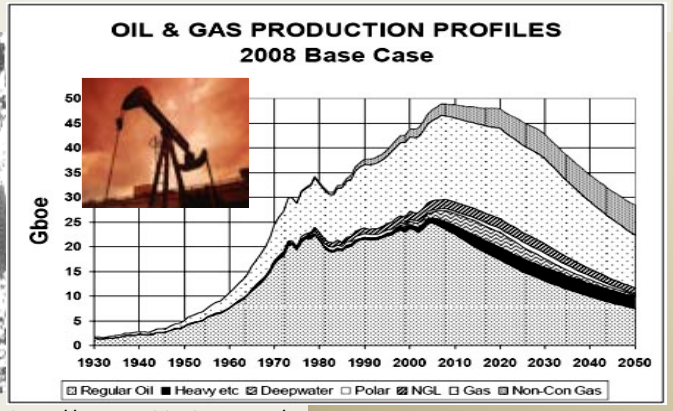
*Intervention Licence 2 «Physiologie végétale tropicale et méditerranéenne»*

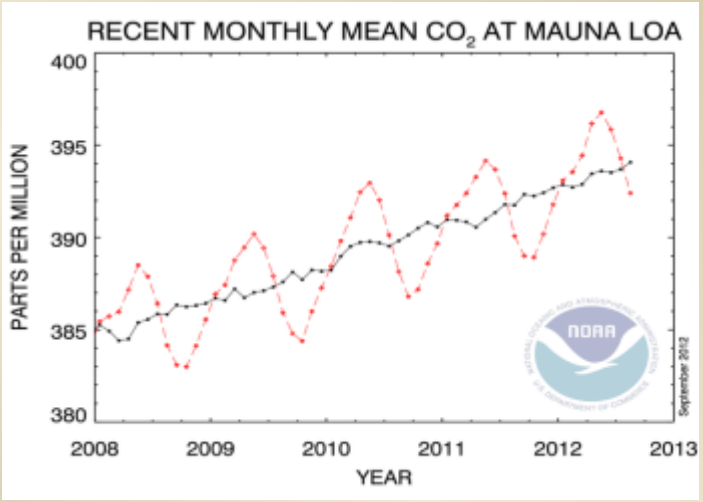
*Université Montpellier 2, 12/02/2013, Montpellier*

# Context

*Global oil production is rapidly approaching its peak*

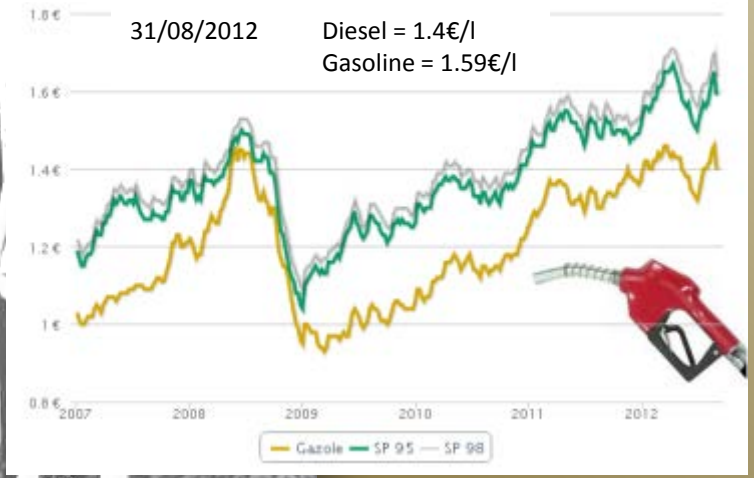



http://www.oildecline.com/




$CO_2$ atmospheric concentration in Aug. 2012 = **392.41 ppm**
http://www.esrl.noaa.gov

**Evolution of price at the gas station**




**It is urgent to find alternative and sustainable energies**

**Biofuels or agrofuels, defined as solid, liquid or gas fuels derived from biomass, are today the only direct subsitute for oil on a significant scale particularly in the transport sector**

# Context

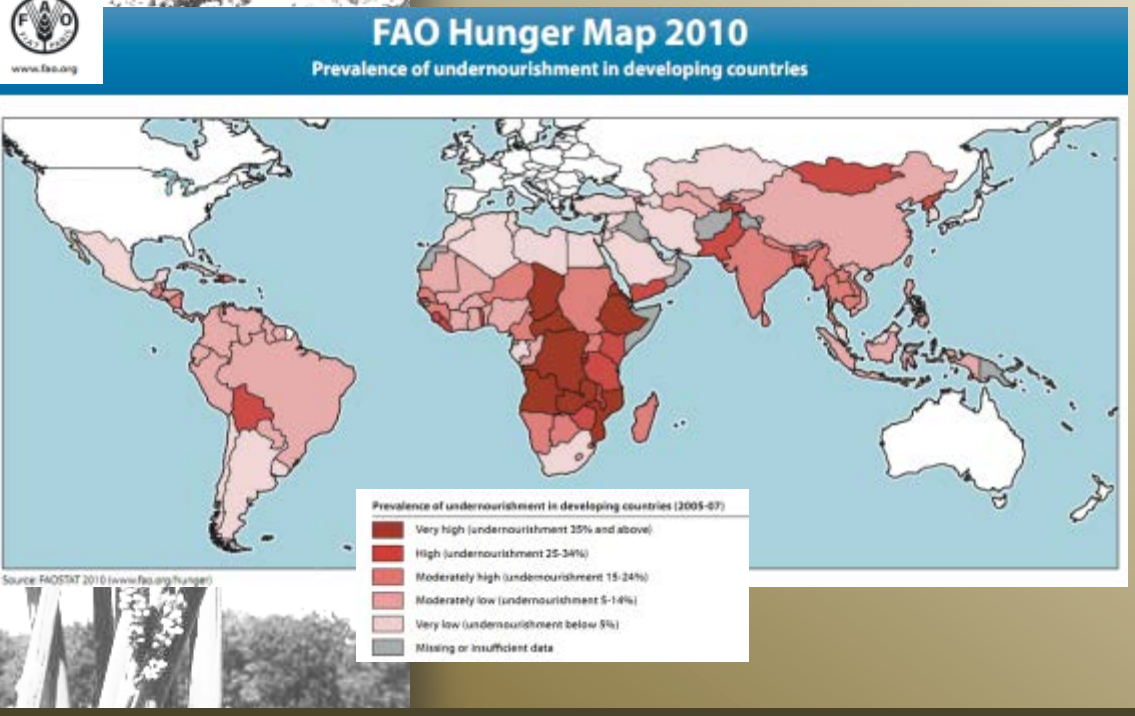
poorest countries will be lead to grow biofuel crops

Less arable surfaces available for food production

Increasing staple food world market prices
(good for producers, bad for urban consumers)

Instability of the staple food market

**Increase of food insecurity**



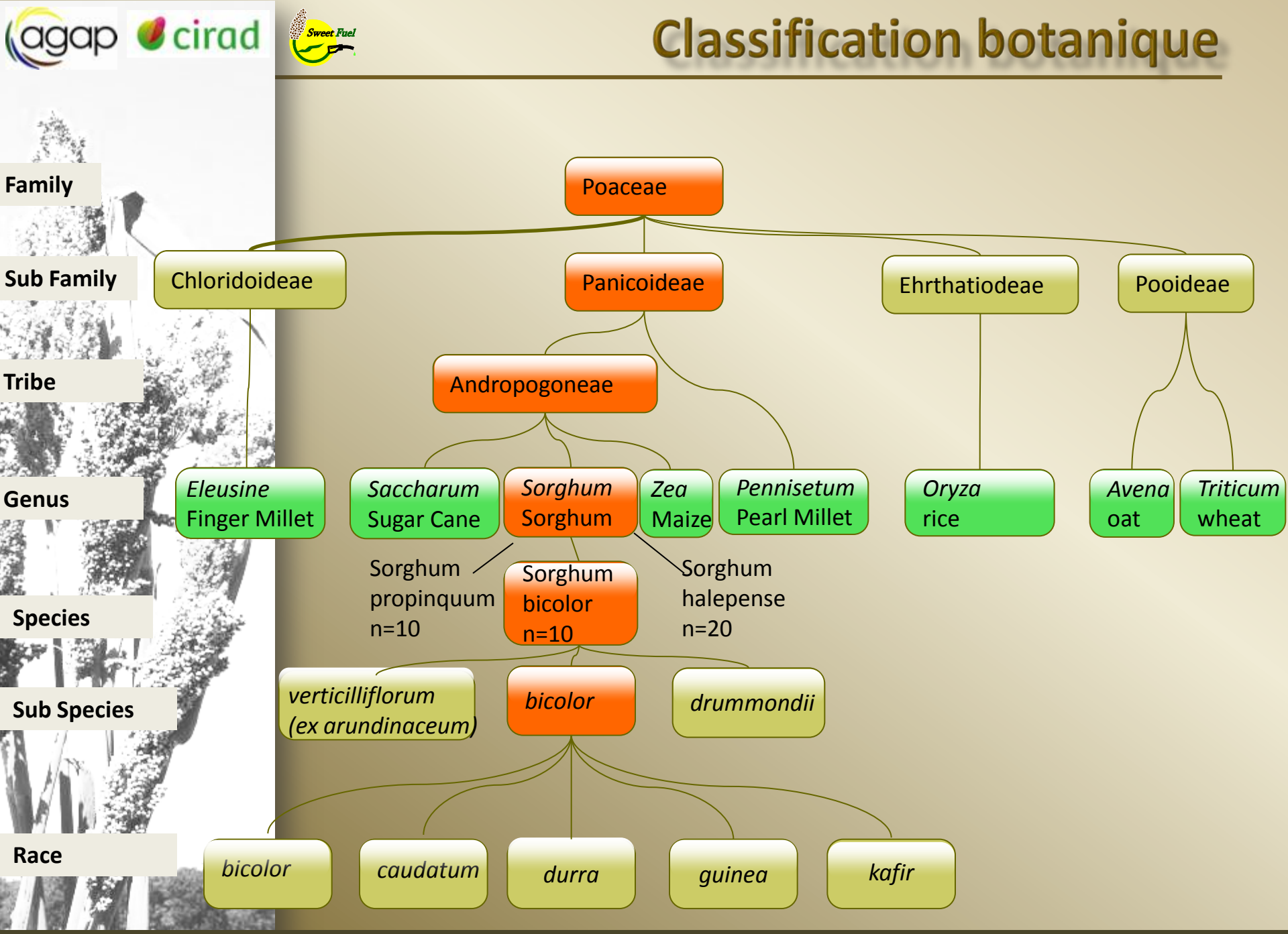
# Les plantes actuelles utilisées pour produire de l'énergie

## Bio-ethanol 1G

## Bio-ethanol 2G

## Bio diesel

# Classification botanique



# Le sorgho: description générale

# Les 5 races de sorgho cultivé

Verticilliflorum
(forme sauvage)

Bicolor

Guinea

Caudatum

Durra

Kafir

# Le sorgho = 5e céréale mondiale

## World production (2010)

| | 2010 Production (million T) | Yield (Kg $ha^{-1}$) |
|---|---|---|
| Maize | 840 | 5195 |
| Paddy rice | 696 | 4368 |
| Wheat | 654 | 3009 |
| Barley | 124 | 2600 |
| Sorgho | 56 | 1361 |

(http://faostat.fao.org/)

# Principaux pays producteurs

| | 2010 Production (millions of tonnes) | Area (1 000 ha) |
|---|---|---|
| USA | 8,8 | 1 948 |
| Mexico | 6.9 | 1 768 |
| India | 6.7 | 7 790 |
| Nigeria | 4.8 | 4 737 |
| Argentina | 3,6 | 751 |
| Éthiopia | 3 | 1 619 |
| Sudan | 2.6 | 5 613 |
| China | 1.7 | 547 |

Pour mémoire, France : 40-50 000 ha

# Usages multiples

Sorgho biomasse

Sorgho ensilage

Sorgho grain

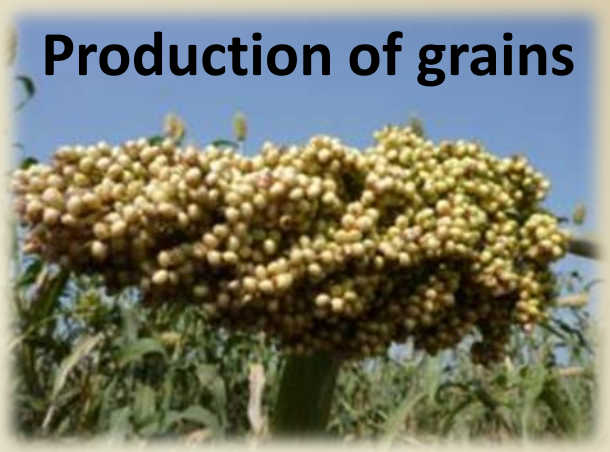
Sorgho à balai

Sorgho teinturier

# Le sorgho sucrier

## Combination of 2 essential traits:

1. Production of grains



2. Accumulation of sugars in the stalks

# Why sorghum for producing ethanol ?


**Tropical zone**

VS


**Propagation**
Cuttings seeds

**Length of cycle**
12-16 months 4-5 months

**Water requirements**
36 000 m3 12000 m3

**Adaptation to dry zones**
Irrigation yes

**Adaptation to marginal soils**
cane < < sorghum

**Grain production**
0 << up to 6T / ha (2 cycles)

**Ethanol production (l ha-1)**
6500 5600 (2 cycles)

**Uses**
Sugar, Fuel Food, Feed, Fuel


**Temperate zone**

VS


**Intrant needs**
sorghum < < maize

**Water requirement**
1/3 less than maize

**Nitrogen Use Efficiency**
sorghum > > maize

**Adaptation to dry environments**
sorghum > > maize
(stay green)

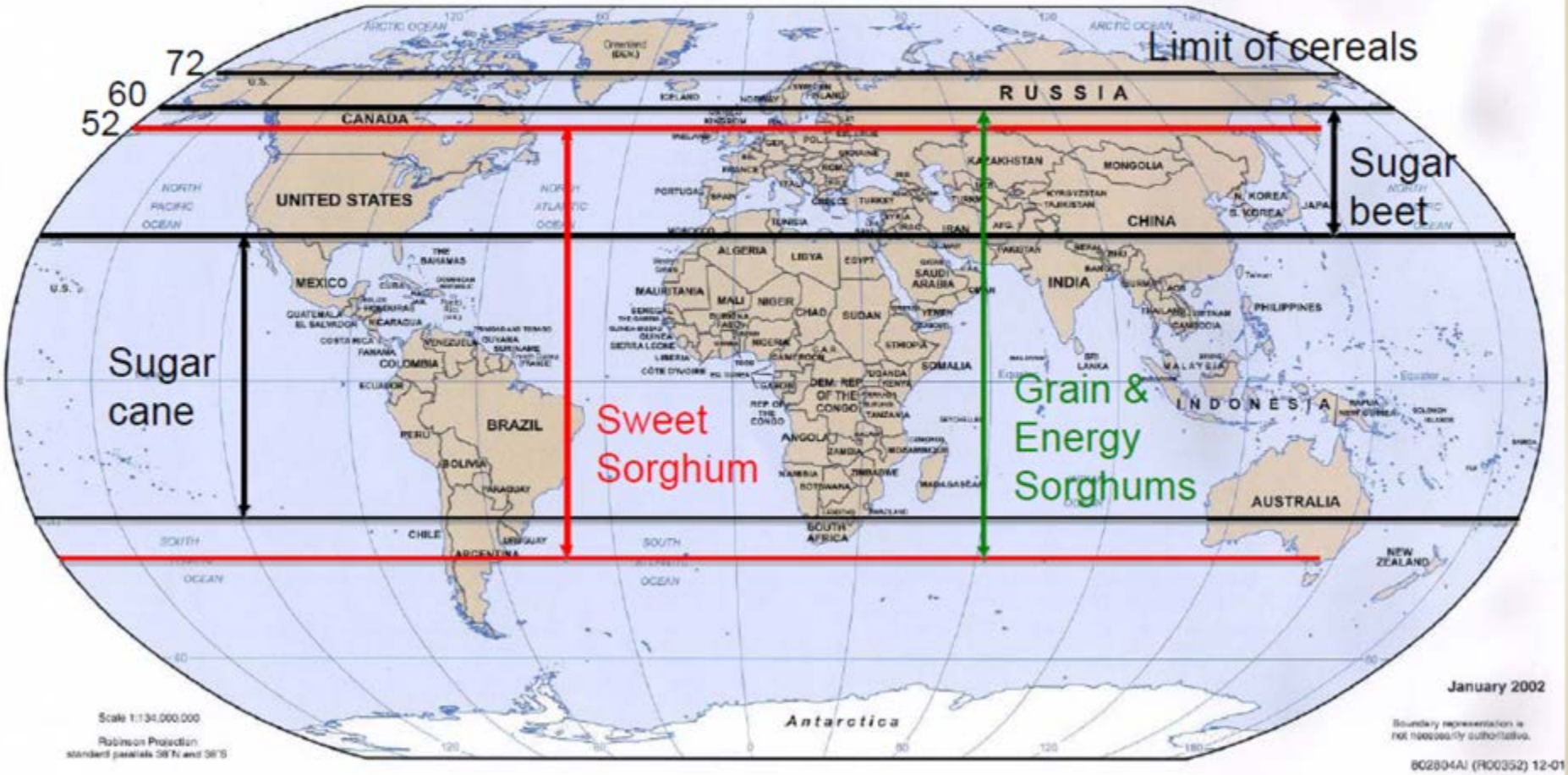
**Adaptation to marginal soils**
sorghum > > maize

**Biomass**
sorghum ⇔ maize
(25 to 40T DM ha-1)

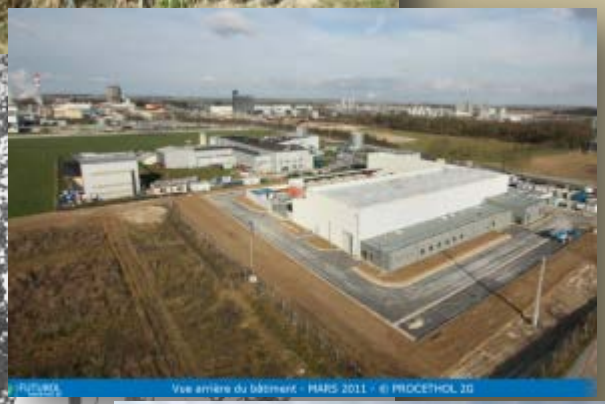
***ADVANTAGE SORGHUM***

**Hudge potential of improvement and adaptation**
**Respect of environment**
**Development of rural zones**
**Low competition with food crop**
**Better sustainability of the production system**

# Why sorghum for producing ethanol ?



# Quel sorgho pour quel biocarburant ?



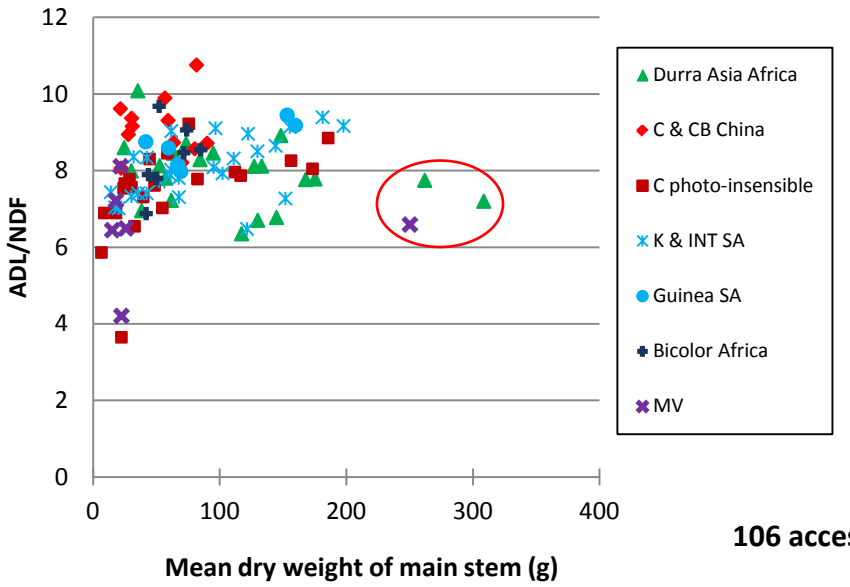
❶ **2nd generation EtOH** or **methane production :** a **biomass sorghum** with the following traits:

- ✓ **High biomass** production (30-40 TDM ha $^{-1}$) which means a plant height > 3.5-4m and a long cycle (4-5 months)
- ✓ good **tolerance to low temperature**
- ✓ a **photosensitivity** adapted to induce flowering by the end of August
- ✓ a **good quality** of the raw material which must be poor in lignin (*bmr* trait) to increase **digestibility** of the tissues
- ✓ a good **tolerance to lodging** (antagonistic with *bmr* trait)
- ✓ **tolerance to water deficit** / high water use efficiency

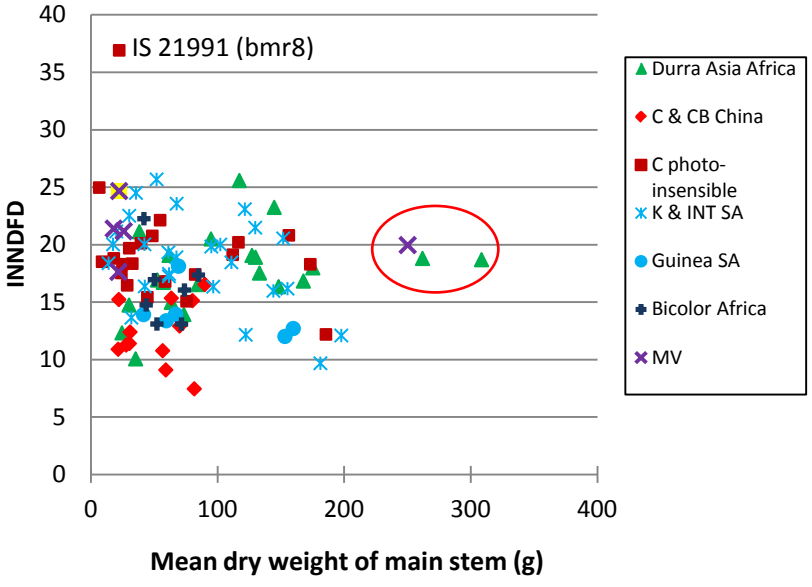
**for that purpose, grain production is not essential**

# What sorghum for what biofuel ?

## 2nd generation EtOH or methane production : a biomass sorghum




106 accessions

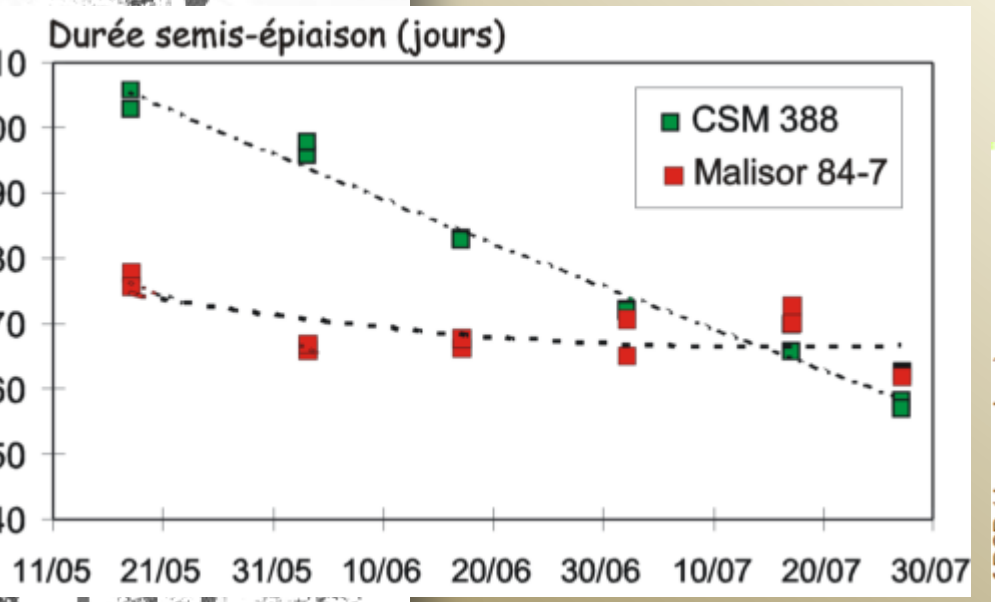



Possible combination of
+ high stalk biomass
+ low lignin content
+ good digestility of fibres

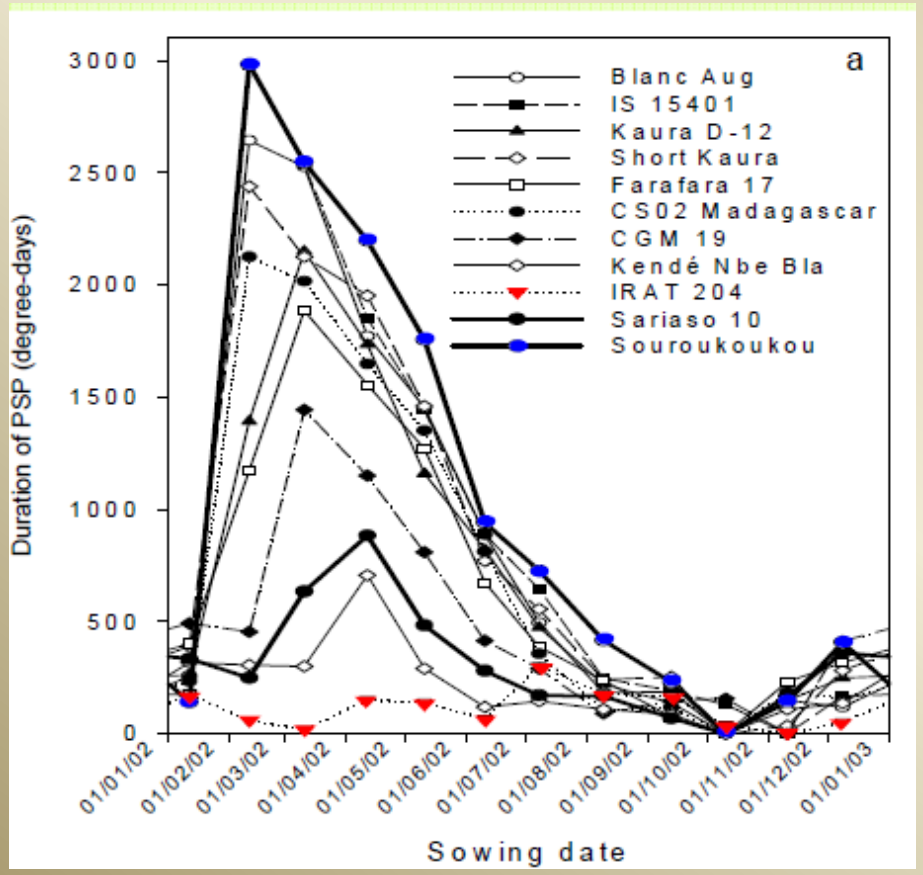
# What sorghum for what biofuel ?

1

**2nd generation EtOH** or **methane production :** a **biomass sorghum**




Photosensitivity



# What sorghum for what biofuel ?

2

**1st generation EtOH** or **cogeneration :** a **sweet sorghum** with the following traits:

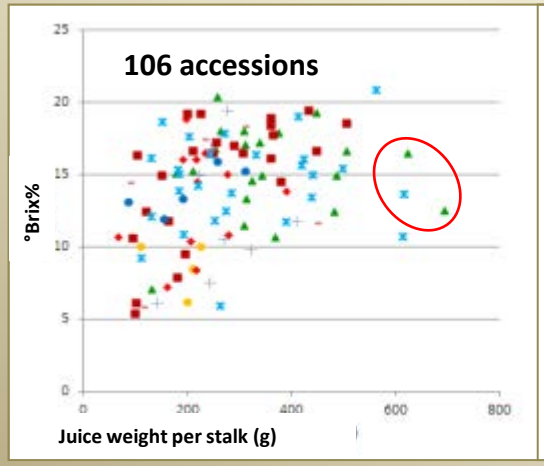
- ✓ **High biomass** production (30-40 TDM ha $^{-1}$) which means a plant height > 3.5-4m
- ✓ high accumulation of **soluble sugars in stalks**, °Brix% of 15 to 20 with 80% of saccharose
- ✓ **juicy** stalks
- ✓ high **energetic value of the bagasse** for cogeneration which means more fiber with lignin)
- ✓ adaptation to **marginal soils** (acidity, Al toxicity, P deficiency)
- ✓ **adaptation of crop cycles** (complementary with sugar cane)

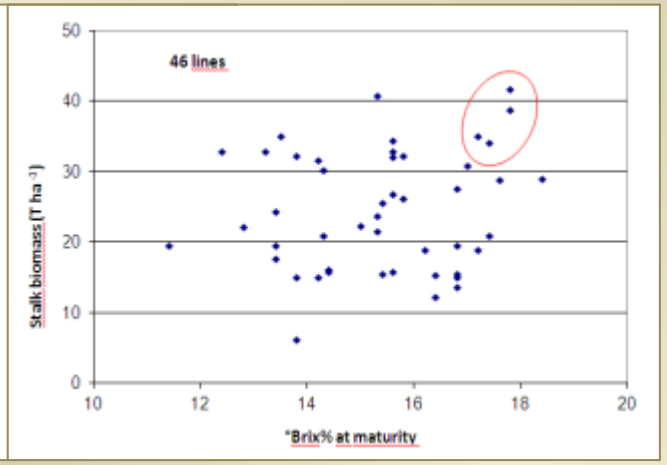
**for that purpose, grain production is not essential (if not undesirable)**

# What sorghum for what biofuel ?

2

## 1st generation EtOH or cogeneration : a sweet sorghum (cas du Brésil)



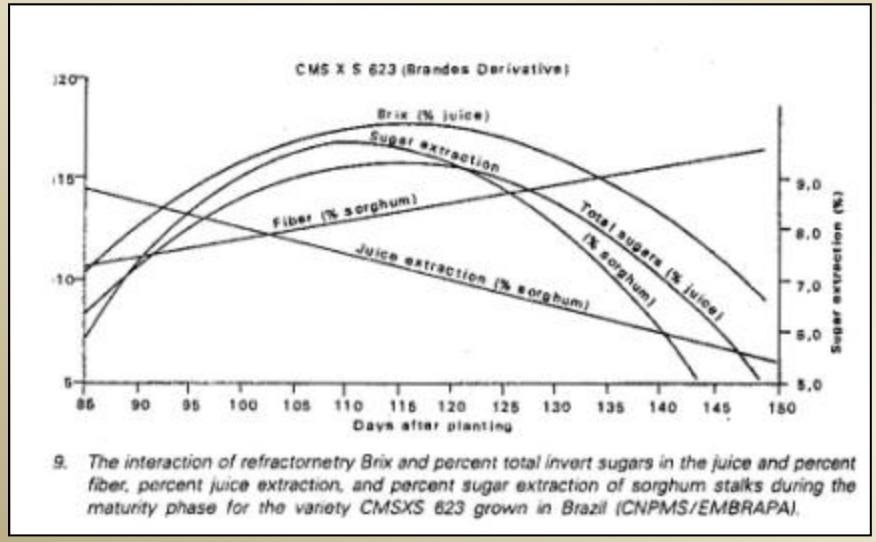




gene for tolerance to
aluminum toxicity : ***Alt$_{SB}$***

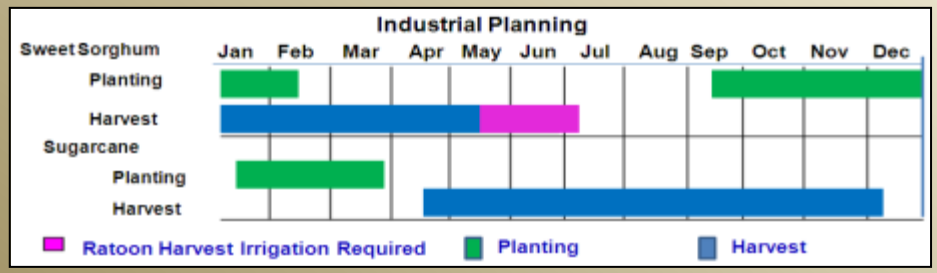
# What sorghum for what biofuel ?

2

## 1st generation EtOH or cogeneration : a sweet sorghum (cas du Brésil)




9. *The interaction of refractometry Brix and percent total invert sugars in the juice and percent fiber, percent juice extraction, and percent sugar extraction of sorghum stalks during the maturity phase for the variety CMSXS 623 grown in Brazil (CNPMS/EMBRAPA).*




Possible combination of
+ °Brix% with juice
+ °Brix% with stalk biomass
+ Al tolerance
+ complementarity sugar cane cycles (1.8 million ha)

# What sorghum for what biofuel ?

Planting

Harvest

Transformation

# What sorghum for what biofuel ?

3

**1st generation EtOH** combining with **grain** and **fodder**: a sweet sorghum with the following traits:

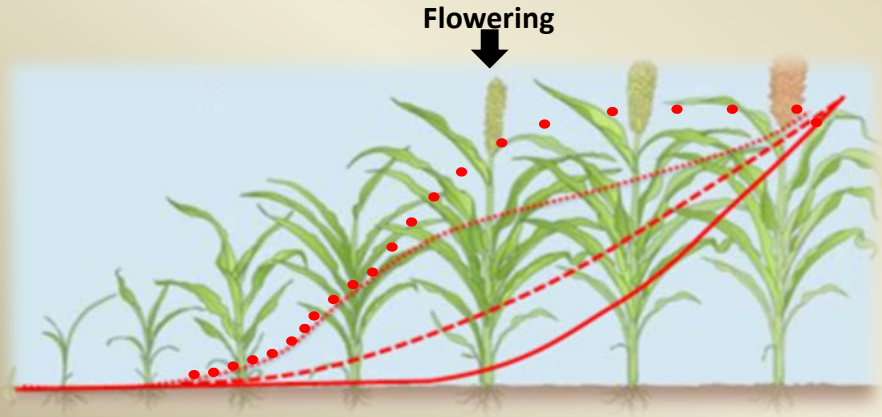
- ✓ **High biomass** production (20-30 TDM ha $^{-1}$) which means a plant height ± 3m and a long cycle (4-5 months)
- ✓ a mean production of **grain** (1.5 to 3 T ha $^{-1}$)
- ✓ high accumulation of **soluble sugars in stalks**, °Brix% of 15 to 20 with 80% of saccharose
- ✓ **juicy** stalks
- ✓ high value of the **bagasse as fodder** which means high digestibility (=*bmr* trait = low lignin content in bagasse)
- ✓ adaptation to **marginal soils** and **rainfall distribution** (stay green, adapted photosensitivity)

**for that purpose, grain production is essential**

# Accumulation of sugar in stalks

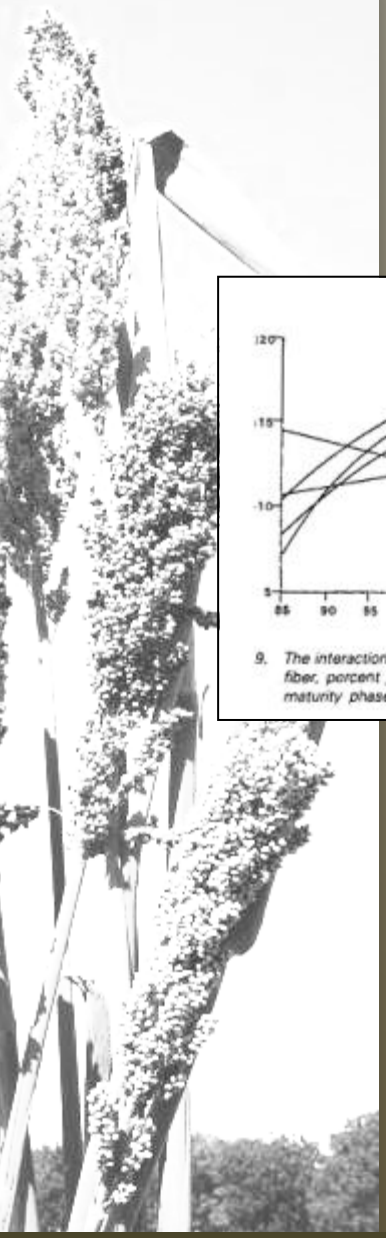
**Processes of accumulation are not well characterized**

**What is the right kinetic of sugar accumulation in stalks ?**

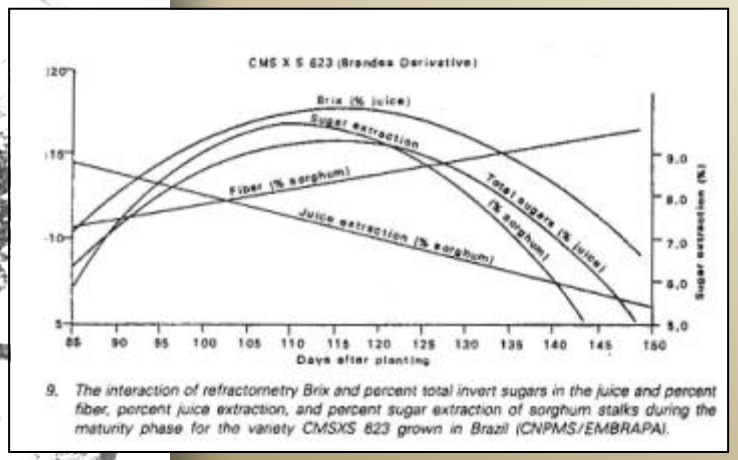



**Is there a competition between sugar accumulation and grain production ?**

# Accumulation du sucre chez le sorgho



Mesure la plus fréquente: le °Brix%

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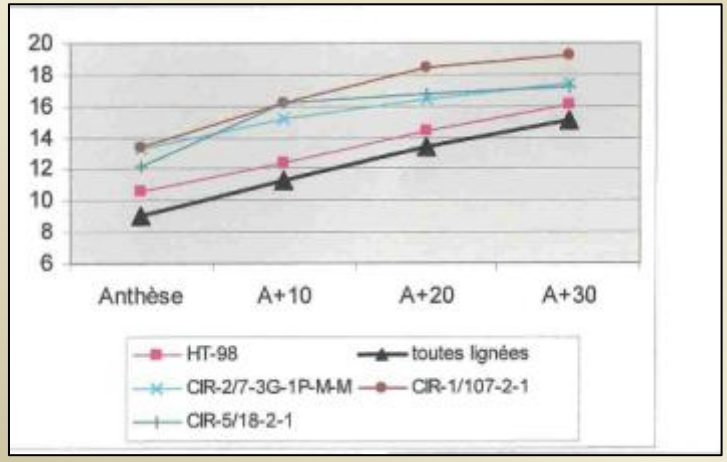
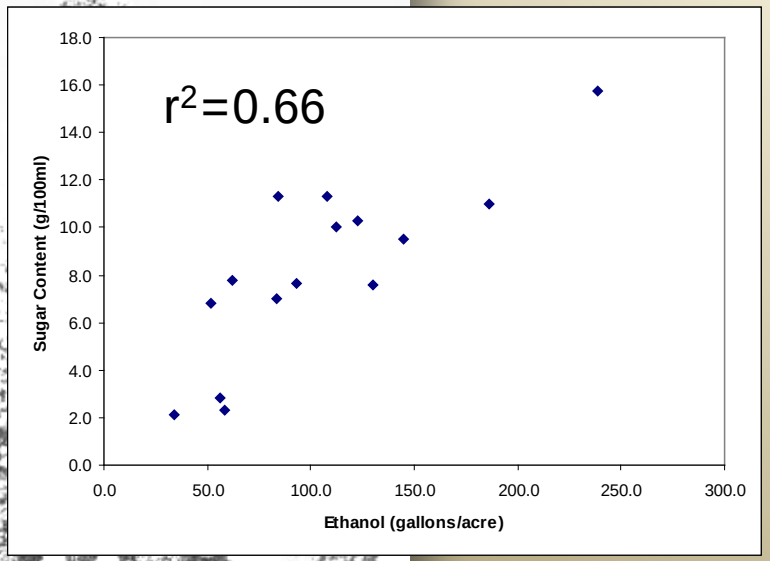
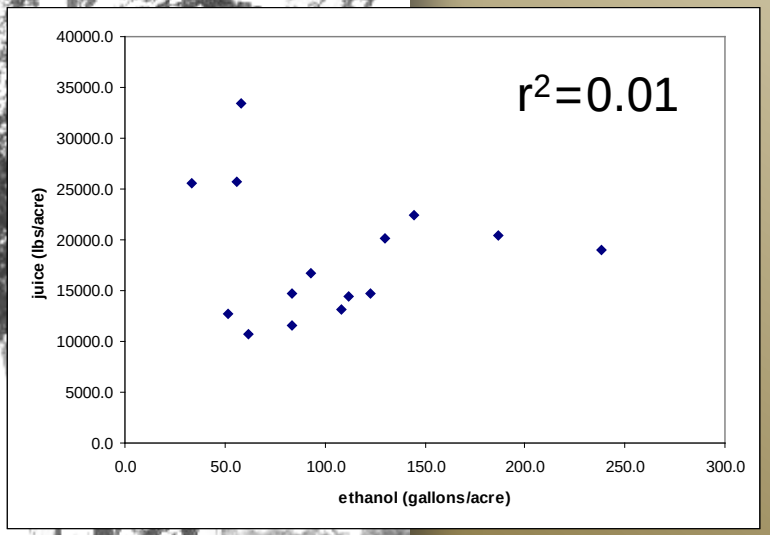



**Résultats différents, voire parfois contradictoires**

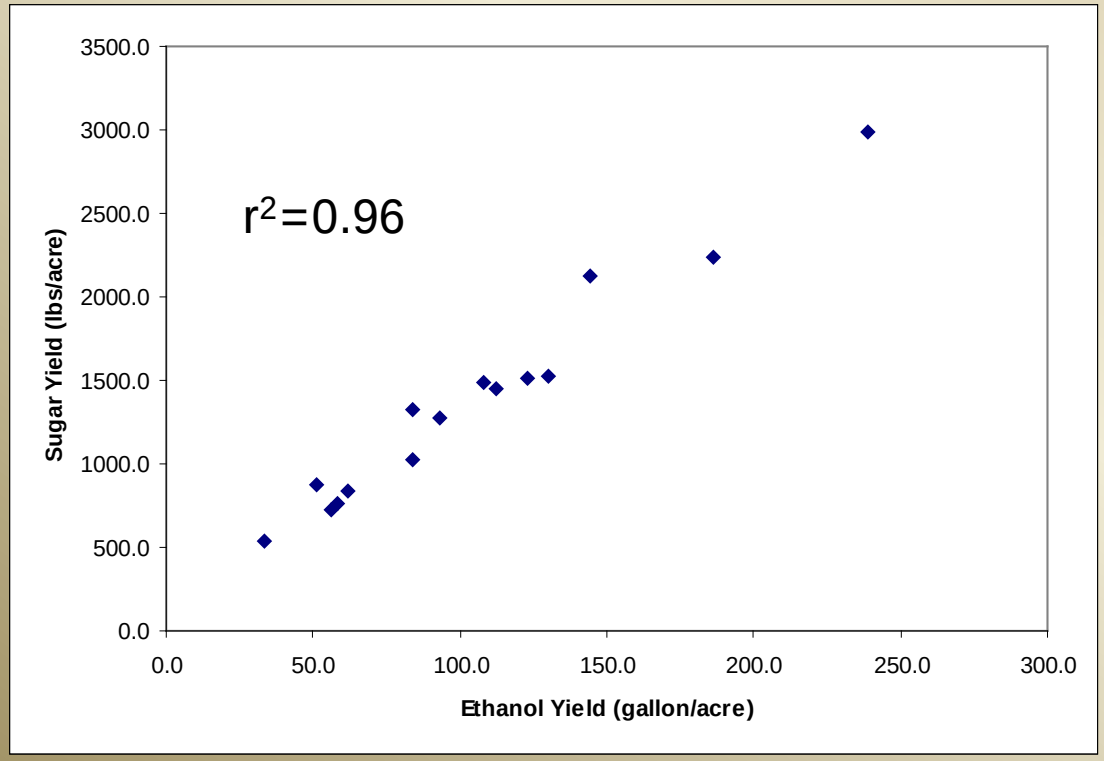
# Mesure fiable de la quantité de sucres dans les tiges




Mesure de la teneur en sucre du jus par le °Brix%

le °Brix% seul ne rend pas correctement compte de la quantité de sucres produite. Il faut °Brix% + jus




(From W. Rooney, 2012)

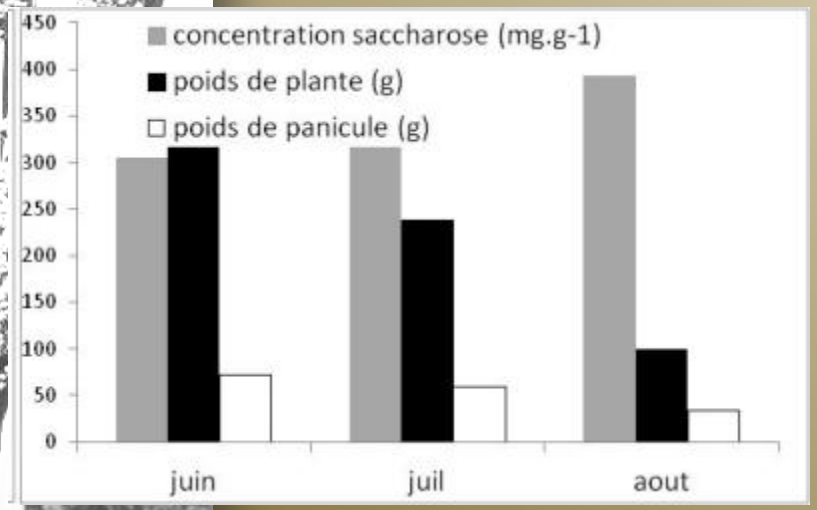
# Compétition grains/sucres ?

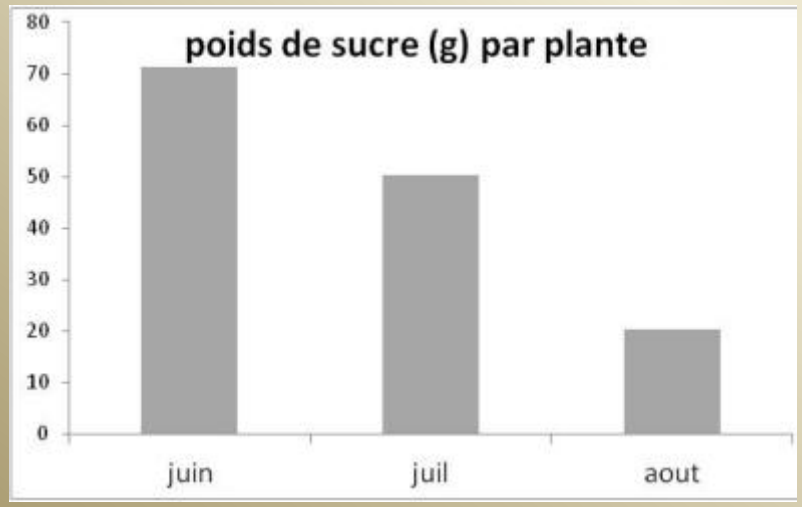
(Source: Gutjahr 2012)

l'accumulation du sucre est proportionnelle à la longueur du cycle

la biomasse végétative et les sucres accumulés sont très plastiques

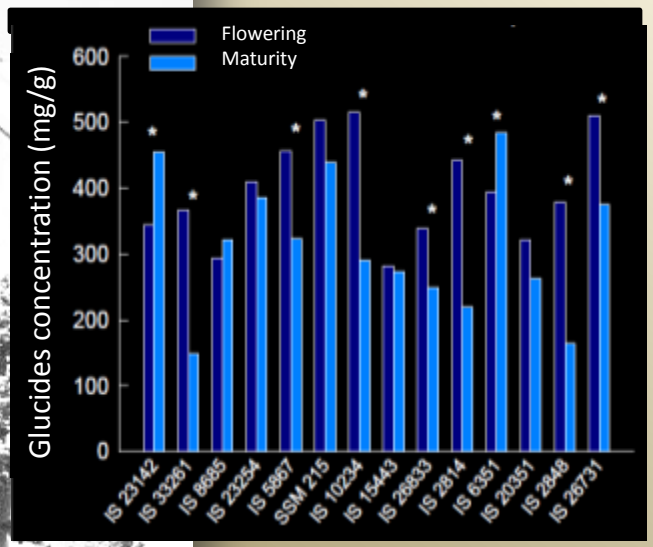
celle de la panicule beaucoup moins

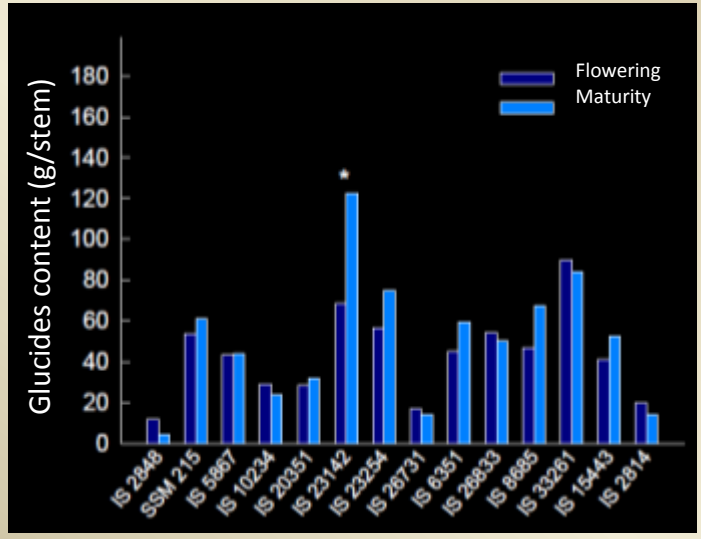


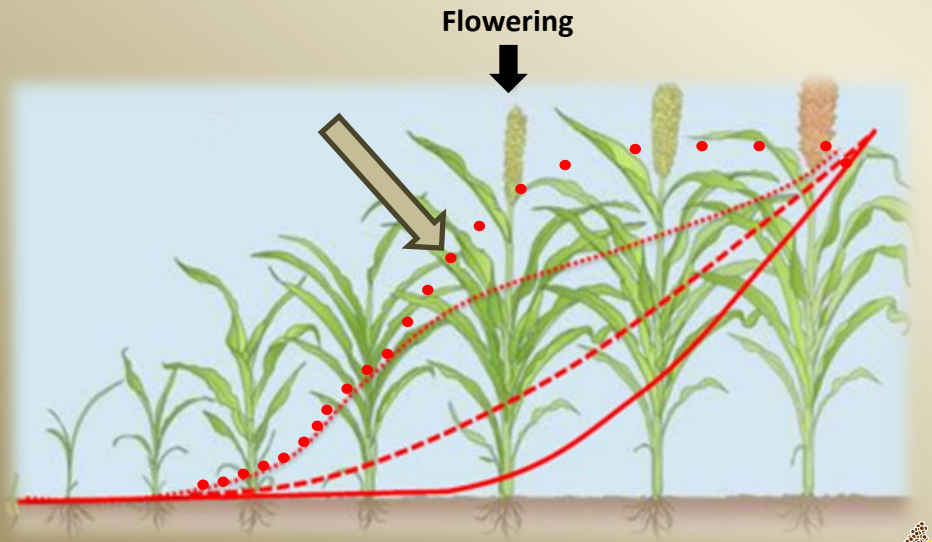
# Accumulation of sugar in stalks

**(Source: Gutjahr 2012)**



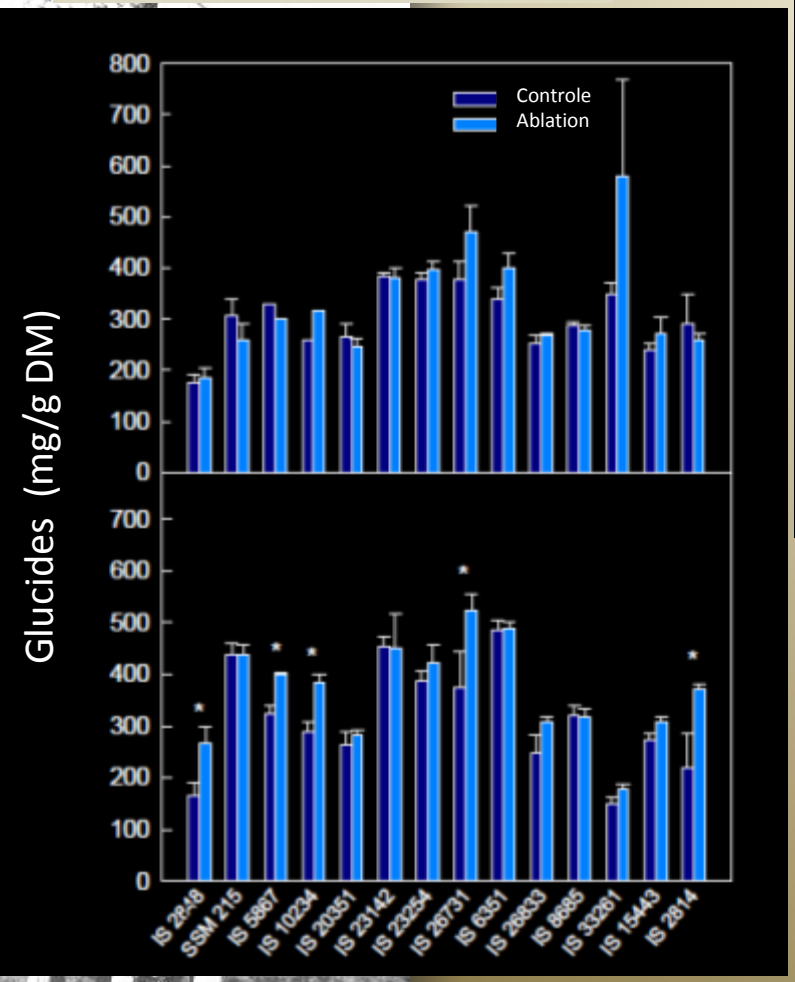

**Glucides are accumulated before flowering**



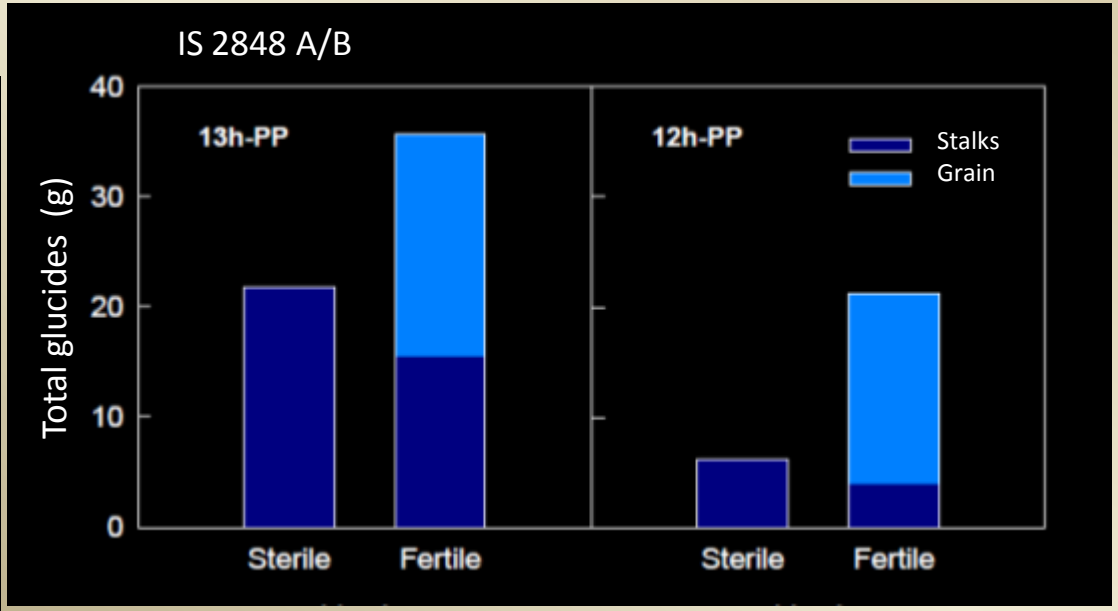
# A competition grain/sugar ?

(Source: Gutjahr 2012)

## Field experiment



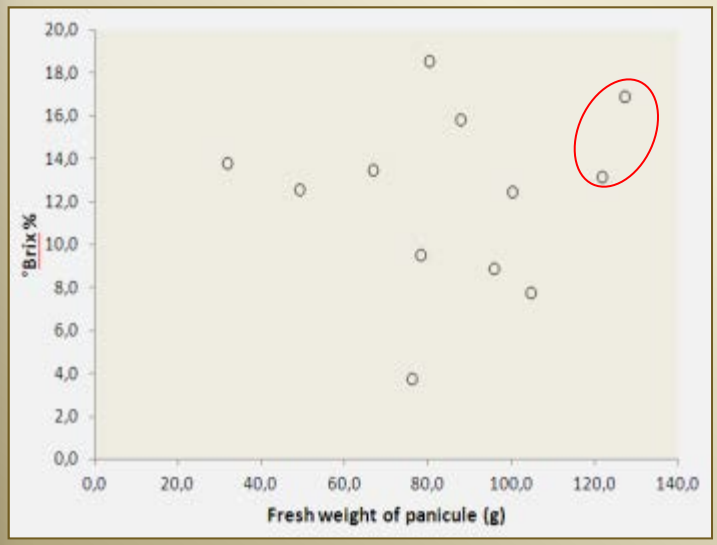

## Grennhouse experiment

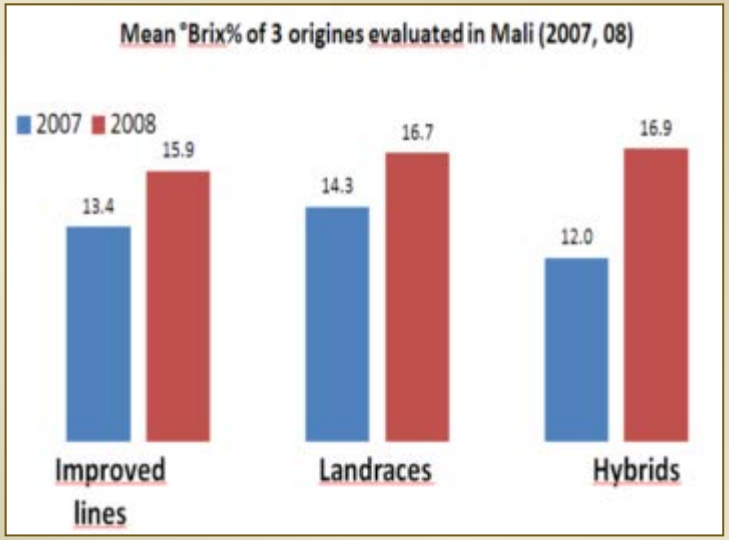



**Ablation of panicule has low influence on sugar accumulation.**

**Competition between sugar accumulation and grain production seems low**
**How the excess of glucides is « consumed » when there is no panicule ?**

# Explorer la diversité




| | |
|---|---|
| **95 T FW Biomass + 5 T grain + 7-12% sugar** | **Almodares et Hatamipour 2011** |
| **60 T DW biomass + 4 T grain + °Brix 18** | **Zhang 2010** |
| **20 T DW biomass + 5 T panicule + °Brix% 16 + 12 T juice** | **Pers. Com. 2011** |
| **65 T DW biomass + 2.2 T grain + 18.7 °Brix%** | **Schaffert 2010** |
| **44.8 T FW cane + 4 T grain + 18.4 T juice + 12 °Brix%** | **S. Rao 2009** |
| **…** | |

Il y a une compétition grain/accumulation de sucres solubles, mais elle ne semble pas très élevée.

On observe une diversité important chez le sorgho qu'il faut explorer sans oublier les variétés locales traditionnelles…

# Project “Biomass for the future” (BFF)

| | |
|---|---|
| **Coordinator:** | **INRA - Institut Jean-Pierre Bourgin (IJPB)** |
| **Budget :** | **Total = ~ 30 million € for a contribution from the government ~ 10 million €** |
| **Duration** | **= 8 years (2013-2020)** |
| **24 partners:** | **public institutions (INRA, CIRAD, Armines)**<br>**+ Private sector (from the sectors of breeding, thermoplastics coumpounds, cement, automotive parts, automotive, plant biotechnology etc..)**<br>**+ local authorities** |
| **2 objectives:** | **1. Development of local miscanthus (North of France) and sorghum biomass (South) production and valorization chains focused on heat-generation, anaerobic digestion and bio-based construction materials and plastics.**<br><br>**2. Creation of new varieties and culture systems for miscanthus and fiber sorghum, with improved lignocellulosic biomass yield, reduced environmental footprint and a composition tailored for industrial uses, including second generation biofuels and platform chemicals.** |

# Autre facteur important: la qualité de la biomasse

**La qualité de la biomasse**

- **Teneur en lignine**
- **Teneur en cellulose**
- **Teneur en hemicellulose**
- **etc…**

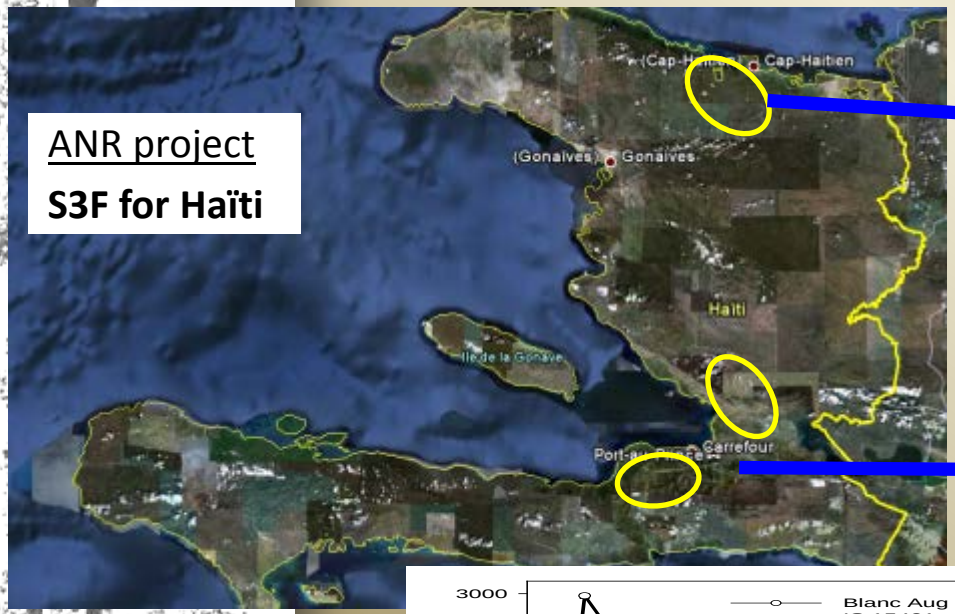
**Pour EtOH 1G, méthanisation, double usage : la lignine est indésirable car les tissus doivent être digérés par des enzymes (2G) ou part les animaux (1G) ou bactéries (méthanisation).**
**Il faut donc des variétés à faible teneur en lignine, donc à caractère *bmr***

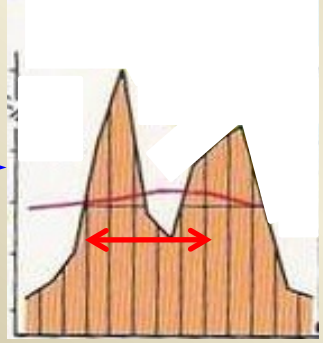
**EtOh 1G (et cogénération): la lignine est souhaitée car elle a un pouvoir calorique élevé**

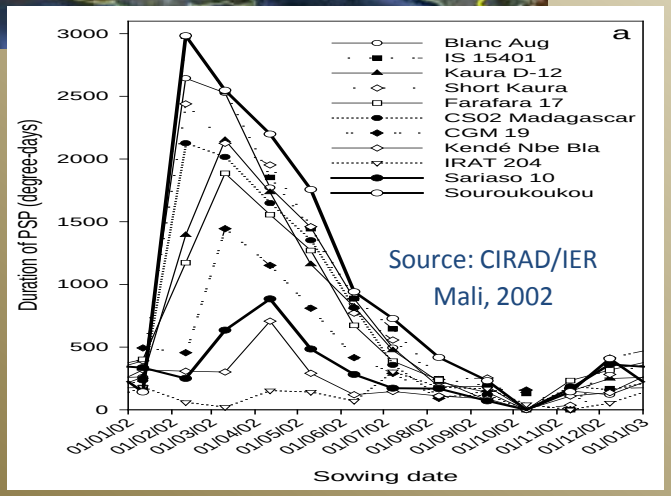
# Autre facteur important

## Cas de Haïti

Idéotype visé: Sorgho triple usage combinant grains + ethanol + fourrage






Adapter la phénologie est essentiel

# Sorgho sucrier: une plante à usages multiples


Food

Feed

Fuel

Fertilizer

Fibers

Bioproducts

...


STOP

Contact:
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www.sweetfuel-project.eu